An Ultrasensitive Trace-Isotope Analyzer

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Abstract

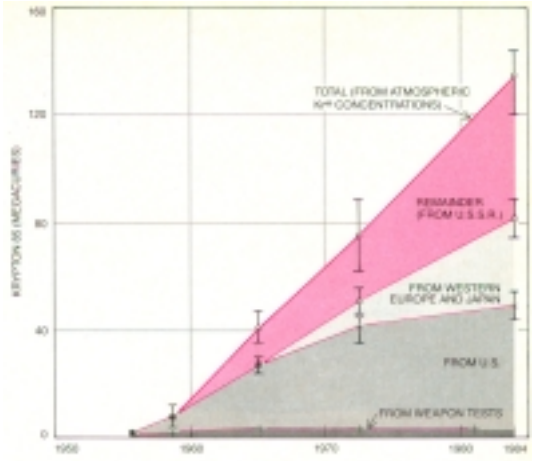
Atom Trap Trace Analysis (ATTA), a technique developed and named at Argonne in 1999, offers a new and sensitive method of detecting traces of nuclear-fission-produced isotopes. It can be used to help verify compliance to the Nuclear Non-Proliferation Treaty. For example, it can be used to detect ^{85}Kr, a noble gas released into the neighboring atmospheric environment during the process of recovering plutonium from nuclear fuels. The analyses of ^{85}Kr in air samples at the ambient concentration level of 10^{-17} have been achieved. Our mid-term goal is to develop an instrument that can detect ^{85}Kr in an air sample as small as 10 ml, which contains about 5000 ^{85}Kr atoms at the ambient level. By counting atoms instead of the traditional way of counting decays, ATTA-enabled instruments are immune to radioactive backgrounds and can be mounted on vehicles for on-site analyses. Moreover, in the event of a nuclear fallout, such instruments can be used to monitor the level of environmental contamination and biological absorption of radioactive isotopes such as ^{90}Sr, ^{135}Cs and ^{137}Cs.

Facts About ^{85}Kr

- Produced by nuclear fission of uranium and plutonium;
- Released into the atmosphere by nuclear fuel re-processing plants;
- In the atmosphere:
  concentration ~ 2 x 10^{-17},
  isotopic abundance ~ 2 x 10^{-11};
- Half-life = 10.8 years.

Applications

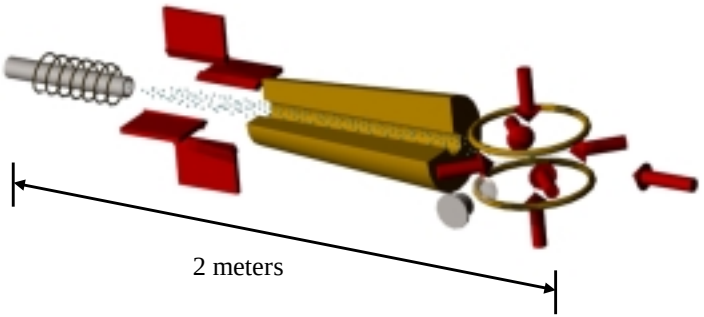
- **Nuclear non-proliferation** – monitor nuclear fuel re-processing activities;
- **Nuclear safety** – Monitor leaks from nuclear fuel containers.



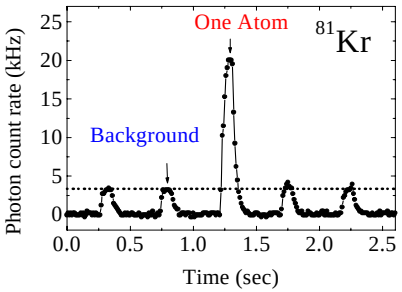
ATMOSPHERIC KRYPTON 85 gives an indication of the size of the U.S.S.R. plutonium stockpile. This isotope is released primarily by nuclear-fuel reprocessing facilities and remains in the atmosphere because it is chemically unreactive. The upper curve, which is based on historical measurements of atmospheric Kr-85 (corrected for radioactive decay), shows the total amount of Kr-85 released to the atmosphere worldwide. The lower curves give the authors' estimates of the contributions to this total originating in weapons tests worldwide and in reprocessing facilities outside the U.S.S.R. The remainder (color) represents an estimate of the amount of Kr-85 released by reprocessing facilities inside the U.S.S.R. It is comparable to the amount released by those in the U.S. Most releases from the U.S. and the U.S.S.R. were probably from facilities producing plutonium for weapons, suggesting that the superpowers' stockpiles of weapon plutonium are also comparable.

Figure copied from *Stopping the Production of Fissile Materials for Weapons*, F. Von Hippel, D.H. Albright, B.G. Levi, Scientific American **253**, 40 (Sept., 1985)

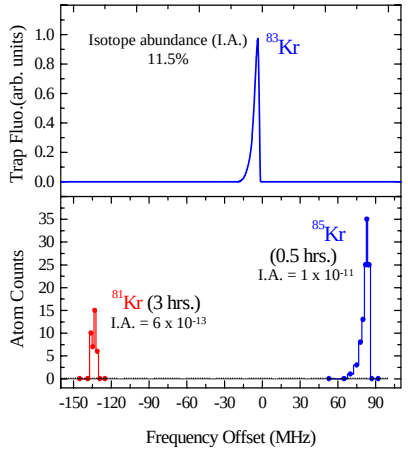
Schematic of an ATTA Setup



Results and Specifications



Single-atom counting -- about 1600 fluorescence photons from a single trapped atom are detected.



Isotopically selective -- atoms of different isotopes are trapped and counted at different laser-frequency settings due to isotope shifts.

Immune to isotope or isobar contamination -- as indicated by a zero background in atom counts.

Sample size required for a 10% measurement --

Present setup -- 1 liter of air
Mid-term goal -- 10 milli-liter of air